# Surface Management System
# Operational Concept Description

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Prepared for
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## Preface

This report was developed from the referenced documents in order to conform to the required contents of an Operational Concept Description (OCD) as jointly defined by National Aeronautics and Space Administration (NASA) and the Federal Aviation Administration (FAA) Free Flight Project Office. The majority of the descriptive material has been taken verbatim from the referenced documents (and noted with square brackets around reference) available at the time of publication. Modifications have been made to add sections not in previous concept descriptions, to improve readability, and to reflect the most currently available information.

This approach to the development of this document was taken in order to remain faithful to the efforts that are presently being undertaken by the NASA Advanced Air Traffic Technologies (AATT) Project Office, the Tool Developers and the associated NASA AATT contractors.

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## 1. Scope

The Operational Concept Description (OCD) of the Surface Management System (SMS) outlines the requirements for and planned operation of a new decision support tool (DST) to improve the efficiency of aircraft operations on the airport's surface. The OCD has a focus of operational and system requirements, and deliberately avoids design information to the extent possible. Specifications are omitted from this document since capabilities to support the SMS should evolve as a result of the research to be conducted.

### 1.1 Identification

This document applies to the Surface Management System, Build 1.

### 1.2 System Overview

**Purpose:** NASA Ames Research Center, in cooperation with the FAA, is developing the SMS, a decision support tool that helps controllers and air carriers collaboratively manage the movements of aircraft on the surface of busy airports, thereby improving capacity, efficiency, and flexibility (References 1, 2, and 3).

**General Nature of the System:**

[The following description of SMS is taken verbatim from Reference 3].

Detailed information about the future departure demand at an airport is not currently available. SMS will provide operational specialists at ATC facilities and air carriers with accurate predictions of the future departure situation. SMS will predict departure demand over a time horizon similar to that over which the Center-TRACON Automation System (CTAS) Traffic Management Advisor (TMA) supports arrival management (References 4 and 5), using surface surveillance, surface trajectory synthesis algorithms that are functionally equivalent to the CTAS airborne trajectory modeling algorithms, and air carrier predictions of when each flight will want to push back. SMS will provide near-term predictions of departure sequences, times, queues, and delays for runways or other resources to support tactical control of surface operations, and longer time-horizon forecasts of aggregate departure demand (i.e., total demand per intervals of time) to support strategic surface planning. Initially, SMS will display this information in the ATC tower (ATCT) and air carrier ramp towers. In the future, SMS may also display information in the TRACON Traffic Management Unit ( ), Center TMU, and Airline Operations Centers (AOCs). Displays similar to TMA timelines and load graphs may be used, depending on the recommendations from human factors studies.

SMS will also use its ability to predict the future state of the airport surface to support departure management decisions. For example, SMS will aid the ATCT in constructing departure sequences that efficiently satisfy various departure restrictions (e.g., Miles-in-Trail (MIT) and Expected Departure Clearance Times (EDCTs)). Subsequent development efforts will extend SMS to interoperate with arrival and departure traffic management decision support tools (e.g., the CTAS Final Approach Spacing Tool

(FAST), TMA, and Expedite Departure Path (EDP) tool) to provide additional benefits (e.g., coordination of arrival/departure interactions).

SMS is an ATC tool that will have value for airline customers. The likely scenario is that the FAA would deploy the tool and a data feed would be made available to the airlines. Current development work is being done with airlines so the algorithms can be refined in the field prior to an ATC demonstration. During these evaluations, information requirements for users external to the FAA will be defined.

**History of System Development, Operation, and Maintenance:**

[The following paragraph is taken verbatim from Reference 3].

SMS is an element of the FAA's Free Flight Phase 2 (FFP2) program, and builds on previous surface management work including Anagnostakis (Reference 6), Glass (Reference 7), and Welch (Reference 8). NASA awarded Contract Task Order (CTO) 5, under its Air Traffic Management System Development and Integration (ATMSDI) contract, to a team including Raytheon, Metron Inc., and Booz-Allen & Hamilton, among others, to develop the initial version of SMS described in this OCD. Key milestones include two real-time, controller-in-the-loop simulations (in September 2001 and January 2002) using the Future Flight Central (FFC) ATCT simulation facility at NASA Ames Research Center. SMS was evaluated operationally at Memphis International Airport (MEM) in Federal Express' (Fed Ex's) ramp tower in August and October 2002. Evaluations of SMS in the Memphis air traffic control facilities are planned for 2003.

SMS is in the early stages of development, and as such, there are numerous aspects of its capabilities and functions that are not well known at this time. NASA is developing Build 1 of SMS through Technology Readiness Level (TRL) 6. There are no specific plans to go beyond Build 1 within the AATT Project. As work continues, additional detail will be identified; elements of the concept may also change, especially as a result of user involvement. This effort will also build the foundation for future surface automation. This initial SMS development will not explore every opportunity for surface management automation. Subsequent research and development will add additional capabilities to SMS in phases. For example, taxi route planning and runway crossing functionalities are being considered. Furthermore, opportunities exist for automation tools to interact with SMS to provide additional benefits. Future versions of SMS may interoperate with TMA to permit arrival/departure tradeoffs (Reference 9), and with FAST and EDP to provide tactical arrival/departure interoperability (i.e., coordinate how individual arrivals and departures share airport resources).

**Project Sponsor, Acquirer, User, Developer, and Maintenance Organizations:** The NASA AATT Project is the sponsor of SMS; the developers are the NASA Ames Research Center. If implemented, the FAA will be the acquirer, user, and maintenance organization.

**Current and Planned Operating Sites:** Field tests of Build 1 SMS are planned for Memphis in 2003. There are no current or planned operating sites.

**Other Relevant Documents:** Documents relevant to the SMS concept are found in Section 2.

### 1.3 Document Overview

The AATT National Airspace System (NAS) OCD (Reference 10) documents current research and provides concept guidance for all AATT projects. It was designed with the understanding that each project element would require a separate OCD of a subset or domain in the NAS in which a particular deficiency is addressed. This OCD is intended to provide guidance for SMS requirements development, to address how SMS fits into the overall NAS, and to provide a means to help transfer this technology to the FAA.

This document is organized according to a format based on the IEEE J-STD-16-1995 standard. Descriptions of the OCD sections follow.

**Section 1. Scope:** This section contains a full identification of the system to which this OCD applies. It briefly states the purpose of the system; describes the general nature of the system; summarizes the history of system development, operation, and maintenance; identifies the project sponsor, acquirer, user, developer, and maintenance organizations; identifies current and planned operating sites; summarizes the purpose and contents of this document; describes any security or privacy protection considerations associated with its use; and lists other relevant documents.

**Section 2. Referenced Documents:** This section lists the number, title, version, date, and source of all documents referenced in this OCD.

**Section 3. Current System/Situation:** This section describes the background, mission, objectives, and scope of the current system/situation including applicable operational policies and constraints and a description of the current system/situation. The description includes, as applicable:

- The operational environment and its characteristics
- Major system components and the interconnections between these components
- Interfaces to external systems or procedures
- Capabilities/functions of the current system
- Charts and accompanying descriptions depicting input, output, data flow, and manual and automated processes
- Performance characteristics, such as speed, throughput, volume, and frequency
- Quality attributes, such as reliability, maintainability, availability, flexibility, portability, usability, and efficiency
- Provisions for safety, security, privacy protection, and continuity of operations in emergencies

In addition, a description of the types of users or personnel involved in the current system is included. This section also provides an overview of the support strategy for the current system.

**Section 4. Justification for and Nature of Change:** This section describes new or modified aspects of user needs, threats, missions, objectives, environments, interfaces, personnel, or other factors that require a new or modified system. It summarizes deficiencies or limitations in the current system that make it unable to respond to these factors. All new or modified capabilities/functions, processes, interfaces, or other changes needed to respond to these factors are summarized in this section. In addition, this section identifies priorities among the needed changes; changes considered but not included; the rationale for not including them; and, any assumptions and constraints applicable to the identified changes.

**Section 5. Concept for a New or Modified System:** This section describes the background, mission or objectives, and scope of the new or modified system and any applicable operational policies and constraints and a description of the new or modified system. The description includes, as applicable:

- The operational environment and its characteristics
- Major system components and the interconnections between these components
- Interfaces to external systems or procedures
- Capabilities/functions of the new or modified system
- Charts and accompanying descriptions depicting input, output, data flow, and manual and automated processes
- Performance characteristics, such as speed, throughput, volume, and frequency
- Quality attributes, such as reliability, maintainability, availability, flexibility, portability, usability, and efficiency
- Provisions for safety, security, privacy protection, and continuity of operations in emergencies

In addition, a description of the types of users or personnel involved in the new or modified system is included. This section also provides an overview of the support strategy for the new or modified system.

**Section 6. Operational Scenarios:** This section describes one or more operational scenarios that illustrate the role of the new or modified system, its interaction with users, its interface to other systems, and all states or modes identified for the system.

**Section 7. Summary of Impacts:** This section describes anticipated operational, organizational, and development impacts on the user, acquirer, developer, and maintenance organizations.

**Section 8. Analysis of the Proposed System:** This section provides a qualitative and quantitative summary of the advantages, disadvantages, and/or limitations of the new or modified system. Major system alternatives, the tradeoffs among them, and rationale for the decisions reached are also provided.

**Section 9. Notes:** This section contains general information that will aid the reader's understanding of this OCD. It includes an alphabetical listing of all acronyms and abbreviations and their meanings as used in this document, and a list of terms and definitions.

## 2. Referenced Documents


1. Anon., “Surface Management System Research Management Plan, Version 1”, FAA/NASA IAIPT, July 2000.
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4. Erzberger, H., Davis, T., and Green, S., "Design of Center-TRACON Automation System," *AGARD Meeting on Machine Intelligence in Air Traffic Management*, Berlin, Germany, May 1993.
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6. Anagnostakis, I., Idris, H., Clarke, J.-P., Feron, E., Hansman, R. J., Odoni, A., and Hall, W., “A Conceptual Design of a Departure Planner Decision Aid,” *3’rd USA/Europe ATM R&D Seminar*, Napoli, Italy, 2000.
7. Glass, B., “Automated Data Exchange and Fusion for Airport Surface Traffic Management,” *AIAA GNC Conference*, AIAA-97-3679, 1997.
8. Welch, J., Bussolari, S., and Atkins, S., “Using Surface Surveillance to Help Reduce Taxi Delays,” *AIAA GNC Conference*, August 2001.
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11. Anon, “FAA Order 7210.3S; Facility Operation and Administration”; February 2002.
12. Anon, “FAA Order 7110.65N, Air Traffic Control”; February 2002.
13. Anon, “Operational Evolution Plan”, FAA, December 2002.
14. Anon, “The NASA Aeronautics Blueprint – A Technology for Aviation”, NASA, 2002.
15. Anon, “CTO-05 – Surface Management System (SMS) CTOD 5.16.1 – Updated Human Factors Assessment”, Raytheon, May 31, 2002.
16. Anon, “National Airspace System Concept of Operations Addendum 4: Free Flight Phase 2”, RTCA Select Committee for Free Flight Implementation, 2000.

# 3. Current System/Situation

## 3.1 Background, Objectives, and Scope

Management of surface operations involve a number of service provider and airline/aircraft entities located in the tower, ramps, flight deck (FD) and to a lesser degree the TRACON TMU, the Center TMU, AOC, and the Air Traffic Control System Command Center (ATCSCC). Surface management is enhanced by a shared awareness of the current and future departure situation among these entities.

## 3.2 Operational Policies and Constraints

The operational policies and constraints relevant to the present traffic management system are contained in References 11 and 12:

- *FAA Order 7210.3S, Facility Operation and Administration*; August 2002; Part 3, Terminal Air Traffic Control Facilities is particularly relevant to this OCD.
- *FAA Order 7110.65N, Air Traffic Control*; August 2002; Chapter 3 – Air Traffic Control - Terminal also contains material that describes the operations of the existing surface traffic control system.

## 3.3 Description of Current System or Situation

The importance of increasing airport capacity and decreasing airport gridlock was recognized within the FAA's NAS Operational Evolution Plan (OEP) (Reference 13) that specifies increased arrival and departure rates as one of four major areas of emphasis. The other three areas are en route congestion, airport weather conditions, and en route severe weather. NASA identified similar issues related to traffic optimization within the NASA Aeronautics Blueprint – A Technology for Aviation (Reference 14).

The arrival and departure capacity of an airport is a function of many variables, including the number of runways, airport configuration and geometry, weather, current and future traffic, and other restrictions. Airport capacity and efficiency are often reduced under sub-optimal conditions (e.g., bad weather) and these reductions are exacerbated at airports in which arrival and departure operations are interdependent. To accommodate the projected increase in airport traffic, steps must be taken to increase the current arrival and departure rates while maintaining or improving current levels of air traffic safety.

## 3.4 Users or Involved Personnel

[The descriptions of user personnel roles was taken virtually verbatim from Reference 15.]

The focus of this section is the roles and responsibilities of each of the active participants in the present environment or situation. Users and involved personnel are identified in Table 1. Subsections address the roles and responsibilities of the Air Traffic Service Provider (ATSP), airline ramp/AOC/dispatcher, and the pilot, respectively.

**Table 1. Users/Involved Personnel for Current Operations**

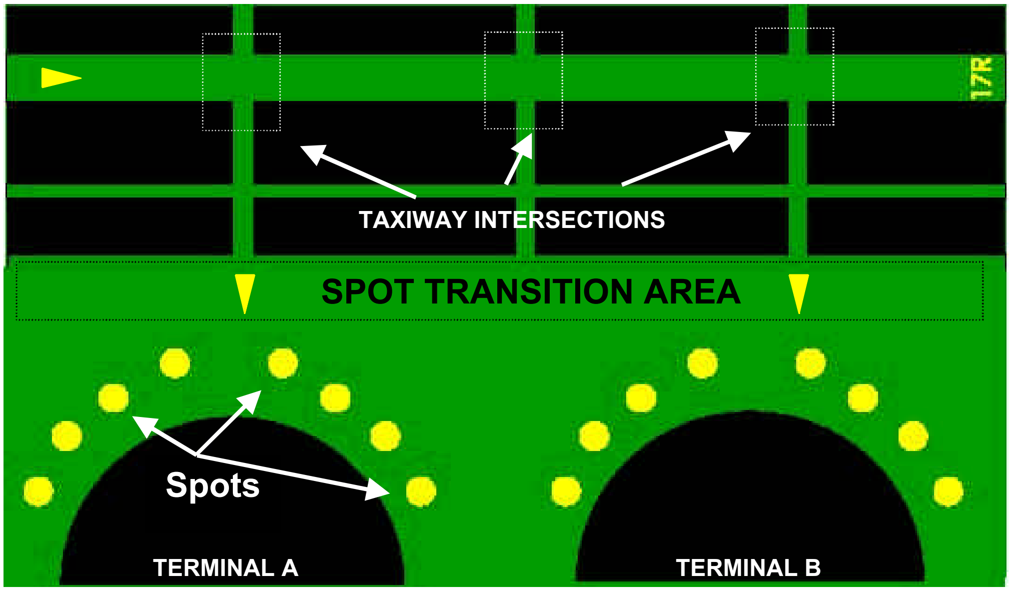
| Users or Involved Personnel | Current Operations |
|---|---|
| Traffic Management Specialist at ATSCSS | ✓ |
| Air Traffic Control Supervisor (ATCS) | |
| Supervisory Traffic Management Coordinator-in-Charge (STMCIC) | |
| Operations Supervisors (OS) | |
| Traffic Management Coordinator (TMC) | ✓ |
| En Route Radar Position – R controller | |
| En Route Radar Associate (RA) – D controller | |
| En Route Radar Coordinator (RC) | |
| En Route Radar Flight Data (FD) Position | |
| En Route Non Radar (NR) Position | |
| Terminal Radar Position – R controller | |
| Terminal Radar Associate (RA) – D controller | |
| Terminal Radar Coordinator (RC) | |
| Terminal Radar Flight Data (FD) Position | |
| Terminal Non Radar (NR) Position | |
| Tower Local Controller (LC) | ✓ |
| Tower Ground Controller (GC) | ✓ |
| Tower Associate | |
| Tower Traffic Management Coordinator (TMC) | ✓ |
| Tower Flight Data Position | ✓ |
| Tower Clearance Delivery/Flight Data Position | ✓ |
| Flight Service Station Specialist (FSSS) | |
| Airline Ramp Tower | ✓ |
| Airline Operations Center (AOC) | ✓ |
| Pilot or Flight Crew (FC) | ✓ |

**ATSP Roles and Responsibilities:** Tower personnel (local controllers, ground controllers, Clearance Delivery/Flight Data Controller, and Supervisors/Traffic Management Coordinator (TMC)) all have a role in management and efficient planning of airport surface operations.

**ATCT Ground Controller Position Description and Responsibilities:** A tower may operate with multiple ground controllers, depending on the airport, airport configuration, and traffic levels. Ground controllers interact with other tower controllers, airline ramp controllers, the tower TMC, and aircraft pilots. The ATCT ground controller is responsible for the movement of departing and arriving aircraft between the spot transition area - the area that separates the gate area from the taxiways - and the active runways (Figure 1).

The ground controller assigns a departure runway to each departing aircraft and issues taxi instructions to the designated runway. These departure runway assignments often require coordination with the local controller to support the current departure strategy. All departing aircraft are under the control of the ground controller from the time they arrive at a spot until they are handed off to the local controller who gives the departure clearance to the aircraft.

**Figure 1. ATCT Ground Controller Diagram**




The ground controller is responsible for all arriving aircraft once the aircraft have crossed the last active runway, and until the aircraft are handed off to ramp control at the spot transition area.

At some airports, the ground controller is responsible for taxiing arrival aircraft to the intersections of active runways (as shown in Figure 1), whereas it is often the responsibility of the local controller to provide the actual clearance for the runway crossing.

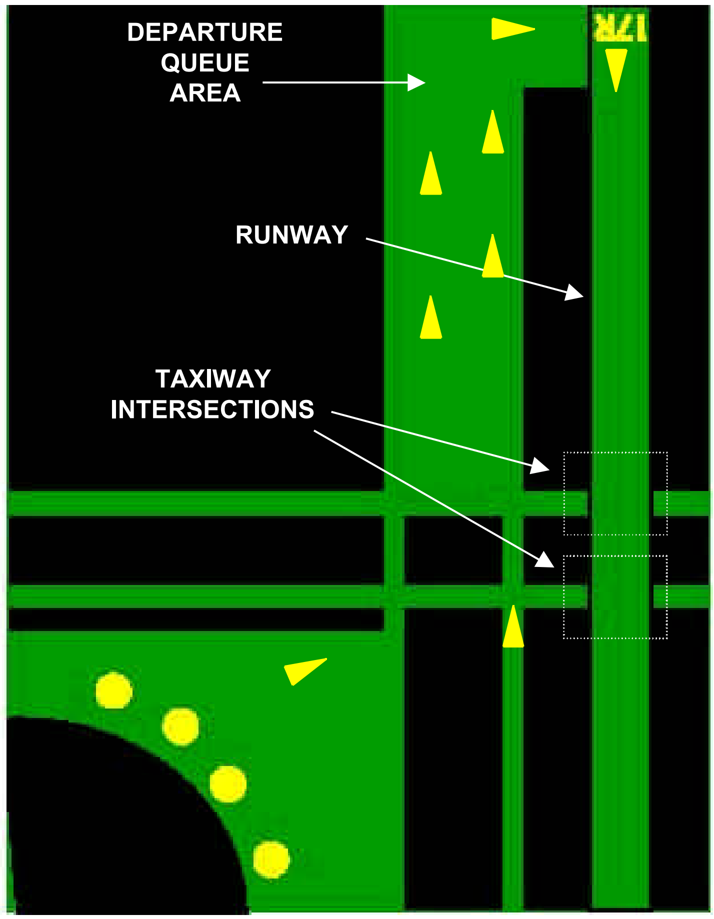
The ground controller is also responsible for managing surface traffic movement. This task requires the controller to monitor aircraft movement on the taxiways, coordinate taxi route assignments, and mix and merge arrival and departure traffic in the transition area.

**ATCT Local Controller Position Description and Responsibilities:** It is common for major airports, based on airport configuration and traffic levels, to operate using multiple local controllers. The local controller frequently interacts with other local controllers, ground controllers, the tower TMC, and pilots.

The ATCT local controller is responsible for all aircraft on and around the active runways (Figure 2). This includes aircraft waiting in departure queues, aircraft taxiing between active runways, aircraft waiting to cross active runways, and airborne arrivals on final approach.

The ATCT local controller issues taxi instructions, indicates to the pilot where the aircraft is to stop and wait for further instructions, and issues takeoff and landing clearances.

**Figure 2. ATCT Local Controller Diagram**




The local controller may alter runway assignments to meet or modify a departure strategy such as using a runway or departure queue only for aircraft destined to a specific departure gate. Alternatively, the local controller may change a runway assignment to optimize runway usage.

At airports in which multiple departure queues feed a single runway, for example Dallas-Fort Worth (DFW), the local controller selects aircraft from the sequences of aircraft in the individual queues that were created by the ground controller. The common controller strategy is to sequence flights with alternating departure fixes to enable minimal departure separation. The local controller provides the takeoff clearance to these aircraft.

When a runway is being used for mixed operations, the controller is required to mix departing aircraft with arriving aircraft. Controllers create slots or gaps in the departure or arrival flow to mix aircraft flows as needed.

At many airports, the local controller also provides clearances to aircraft that need to cross a runway.

**<u>ATCT TMC Position Description and Responsibilities:</u>** The ATCT TMC has four primary responsibilities: (1) handle communications and coordination with other facilities, including the TRACON, Air Route Traffic Control Center (ARTCC), and airline dispatchers; (2) make strategic decisions regarding airport usage, such as runway utilization; and (3) assist other ATCT controllers when workload becomes high..

**<u>Ramp Tower Positions Descriptions and Responsibilities:</u>** Ramp control personnel and their associated responsibilities vary with each airline and from airport to airport. Tables 2 and 3 provide a sampling of ramp control positions and a short description of their responsibilities. These definitions are based on ramp control personnel currently staffed at both the Fed Ex ramp control positions at MEM and the Delta Coordination Center at John F. Kennedy (JFK) International Airport. These figures highlight the fact that potential airline users of SMS have varied support needs.

**Table 2. Fed Ex Operations Position Descriptions at MEM**

| Operations Staff Memphis – Fed Ex | Position Description |
|---|---|
| Ramp Controller Positions | Sector 1: Feeder Ramp, River Ramp, and South Ramp<br>Sector 2: Southeast Ramp<br>Sector 3: Courtyard Ramp<br>Sector 4: Northeast Ramp<br>· Responsible for pushback, arrival, and taxiing of aircraft within their sector |
| Ramp Supervisor | · Oversees push-backs, monitors departure and arrival within ramp, and coordinates with ATC |
| Maintenance Supervisor | · Coordinates all maintenance activities |

**<u>AOC Position Descriptions and Responsibilities:</u>** AOC personnel perform a variety of roles, such as dispatchers, AOC managers, ATC coordinators, weight-and-balance staff, and crew schedulers. To complete their tasks, AOCs must interact with other airline staff (e.g., flight crews, maintenance, and Ramp Control), and with FAA traffic managers at the Air Traffic Control System Command Center (ATCSCC), ARTCCs, and TRACONs. These interactions may be ad hoc, as in the case of seeking prioritization for an individual flight that is low on fuel. Alternatively, these interactions may be part of regularly scheduled communications, such as the ATCSCC Strategic Planning Team teleconferences, which occur every 2 hours each day.

AOC personnel are typically located in a single facility, sometimes co-located with maintenance personnel. AOCs often interact with personnel who are at other sites, either at the same airport (e.g., co-located hub and AOC) or at some other geographically distant location. There are three implications of this distribution of work across physical space and organizations. The first implication is that most of the interactions are done remotely, via a voice connection or some digital form of communication (e.g., Aircraft Communication and Reporting System (ACARS) to communicate with flight crew). This limits the richness of the communications as compared with face-to-face interactions. A second implication is that many of the interactions are asynchronous rather than real-time. Because AOCs often interact with staff from other organizations, such as ATCSCC specialists, the final implication relates to potential competing goals from various organizations.

## Table 3. JFK-Delta Ramp Control Position Descriptions

| JFK-Delta Ramp Control Positions | Description of Basic Functions |
|---|---|
| Manager | · Responsible for the operation of the Ramp Tower |
| Zone Coordinator | · Responsible for flights within their zones.<br>· Coordinates with ramp, services, and catering (whatever is needed to assure that the flight is safe and will depart on time).<br>· Handles pilot scheduling issues |
| Fueling Representative | · Directs the fuel lifts (works for the fueling vendor). This is especially valuable when there is an aircraft change, and fueling personnel need to be directed |
| In-range Coordinator | · Speaks with the aircraft 20 minutes out and addresses any needs<br>· Advises aircraft of gate requirements and any changes that may occur (ACARS messages regarding gate assignment are sent automatically, but Delta requests that aircraft contact them to insure that the aircraft has the most up-to-date information) |
| Master Gate Coordinator | · Monitors gate situations and initiates changes as necessary |
| Kilo Kilo Gate Coordinator | · Administers the aircraft moving in the Kilo Kilo and Kilo taxiways (if Delta needs to use the Kilos, it is required to contact the International Air Terminal (IAT) and arrange that with IAT); IAT in turn will speak to the Kilo Kilo Gate Controller |
| Contract Carrier Coordinator | · Attends to the needs of the contract and connection carriers and movements |
| In-flight Coordinator | · Attends to any problems with the flight attendants (rescheduling, etc). |
| Cargo Transportation Representative | · Works for the cargo vendor; moves cargo to and from the harbor warehouse |
| Delta Cargo Representative | · Monitors the cargo and mail, and attends to all cargo shipments |
| Passenger Connection Representative | · Monitors inbound and outbound flights for the purpose of connecting passengers |
| Catering Representative | · Handles catering needs |
| Cabin Service Representative | · Attends to all cabin-related issues (lavatory servicing) |
| Crew Scheduling Coordinator | · Ensures proper allocation of ground crews |

Understanding this distributed work environment is important when considering how to incorporate SMS support into AOC operations. These issues are considered in more detail in the context of potential SMS use in the following section. The dispatcher, ATC coordinator, and AOC manager positions, all of which are staffed with certified dispatchers, are addressed in more detail later in this section.

**Dispatchers:** Individual line dispatchers are responsible for pre-flight planning and flight following procedures after the aircraft departs. Preflight planning includes determining the best route of flight, determining the fuel necessary for that route, and selecting alternate airports. To accomplish this effort, dispatchers much consider the aircraft type, winds, and payload. In addition, the dispatcher must be aware of any restrictions attributed to Minimum Equipment Lists (MELs), weather, or ATC advisories.

Procedures for flight following require the dispatcher to monitor for unexpected changes in weather, and for changes in air traffic and airport restrictions. The dispatcher must also collaborate with the flight crew regarding route diversions. Lastly, the dispatcher must coordinate with the flight crew and maintenance if airborne mechanical problems occur.

**ATC Coordinators and AOC Managers:** ATC coordinators and AOC managers focus on the aircraft fleet at a strategic level. Although ATC coordinators and AOC managers are involved in some decisions at the individual flight level, much of their work focuses on a bigger picture, such as weather events that require significant reroutes, cancellation of a significant number of flights, or a reduction in overall capacity for an airport. These decisions require a broader consideration of the impact of changes on the overall airline schedule based on current and future predictions of NAS status.

**TRACON TMC Position Description and Responsibilities:** Although often co-located with an ATCT at large airports, each TRACON is responsible for any aircraft leaving an airport within a 50-mile radius. For example, the Boston TRACON facility provides service to 10 airports, including Boston Logan.

The TRACON facility is commonly divided into multiple sectors and a TMU area. Although TRACON sector controllers work tactically with aircraft on a flight-by-flight basis through their individual sectors, TRACON TMCs control arrival and departure traffic flows by opening or closing fixes and jet routes.

The TRACON TMC works as one of several TMCs within the TRACON TMU. The number of TMCs on duty can vary, with each TMC on duty assuming different roles. TRACON TMCs work within the TRACON TMU under the supervision of the TMU supervisor. The number of TMCs working within a specific TRACON is dependent on the amount of traffic controlled and the complexity of the surrounding airspace. TRACON TMCs coordinate and communicate with a number of ATC personnel within and outside the TRACON. They are responsible for monitoring operations within the facility (such as coordinating with sector supervisors regarding controller workload) and for determining when and what type of traffic initiatives (e.g., metering, fix closures) should be implemented.

**ARTCC TMC Position Description and Responsibilities:** ARTCC TMCs are responsible for ensuring the smooth flow of air traffic through the ARTCC airspace. ARTCC TMCs perform a variety of roles within the ARTCC TMU. These varying roles are based on planning and coordination activities relevant to each specific ARTCC.

The ARTCC TMC is one of several TMCs working within the ARTCC TMU. The ARTCC TMC commonly interacts with sector supervisors and other ARTCC TMCs. ARTCC TMCs must also coordinate with TRACON personnel and ATCT TMCs regarding traffic initiatives within the ARTCC.

**ATCSCC Specialist Position Description and Responsibilities:** The Systems Command Center has specialists serving many different positions, with responsibilities ranging from dealing with severe weather to quality assurance. However, the SMS information that would be useful to these positions is likely to be very similar. In general terms, ATCSCC specialists are concerned with how to adjust traffic flows to deal with weather, traffic congestion, or some other disturbance. Such adjustments can be accomplished using, for example, reroute advisories or ground delay programs.

**Flight Deck:** The flight deck is responsible for actual operation of the aircraft requesting and receiving push back and taxi clearance, and overseeing aircraft operations throughout its flight regime.

### 3.5 Support Strategy

**To be determined**

# 4. Justification for and Nature of Change

## 4.1 Justification for Change

Departure taxi delay is the largest of all aviation movement delays and results in the largest addition to direct operating costs (Reference 2). The average taxi-out delay in minutes per flight is approximately twice the airborne delay. Although aircraft burn fuel roughly five times faster when airborne, crew and equipments costs make the spend-rate of taxiing aircraft about two-thirds that of airborne aircraft. Consequently, the cost of taxi-out delay is three times larger than airborne delay. The delays that occur on the airport surface may result either from restrictions on the surface (e.g., airport surface congestion and runway capacity limitations) or from restrictions due to limited capacity of other downstream elements of the NAS. SMS provides information and support for the management and reduction of both types of airport surface delays.

## 4.2 Description of Needed Changes

Surface traffic controllers may not have the necessary information nor time to plan beyond immediate aircraft movements, especially during busy periods. SMS addresses three needed changes: (1) the ability to predict the movement of aircraft on the airport surface and in the surrounding terminal area; (2) the ability to use this prediction engine to plan surface operations; and (3) the ability to disseminate this information and provide appropriate advisories to a variety of users.

SMS is being developed as a surface management tool with the ability to provide varying levels of automated information and decision support for many users. The largest advantage of SMS is the ability to predict future traffic demand on the airport surface. This information aids controllers in better surface management through more efficient tactical and strategic decision-making.

## 4.3 Priorities Among the Changes

SMS products can be grouped into three distinct components to support distinct user requirements: (1) a traffic management tool to support the TMCs in the tower, TRACON and ARTCC, plus the ramp tower supervisor and air carrier AOC; (2) a controller tool to support the tower local and ground controllers, and the ramp tower controllers; and (3) a NAS information tool to support the ATCSCC and air carrier AOCs and ramp tower personnel. However, SMS being developed primarily as an ATC tool that will also be able to benefit airline users.

These fundamental capabilities allow SMS to provide information and advisories about the future situation on the surface that are customized to the needs of each user. SMS could be deployed as three separate tools. SMS Build 1 will support the local and ground controller positions because these were viewed as the most challenging positions to develop SMS support. These positions required the greatest level of aircraft position prediction accuracy compared with the ARTCC, for example, which does not need the exact current position of aircraft on the surface. Instead, the ARTCC would require predicted demand of aircraft departing or arriving at the airport surface.

## 4.4 Changes Considered But Not Included

Build 1 of SMS has limited capabilities and will concentrate on providing a basic information gathering and distribution capability. Subsequent builds may extend SMS to include additional capabilities and interoperate with arrival, departure, and other surface management traffic management decisions support tools.

## 4.5 Assumptions and Constraints

To predict the near-term state of traffic on the surface, SMS assumes an interface to a real-time surface surveillance system that provides aircraft identity (from Airport Surface Detection Equipment (ASDE)-X or similarly capable system. To predict departure times farther in advance (i.e., prior to aircraft pushback), SMS assumes it has airline-provided information about when each aircraft will want to push back.

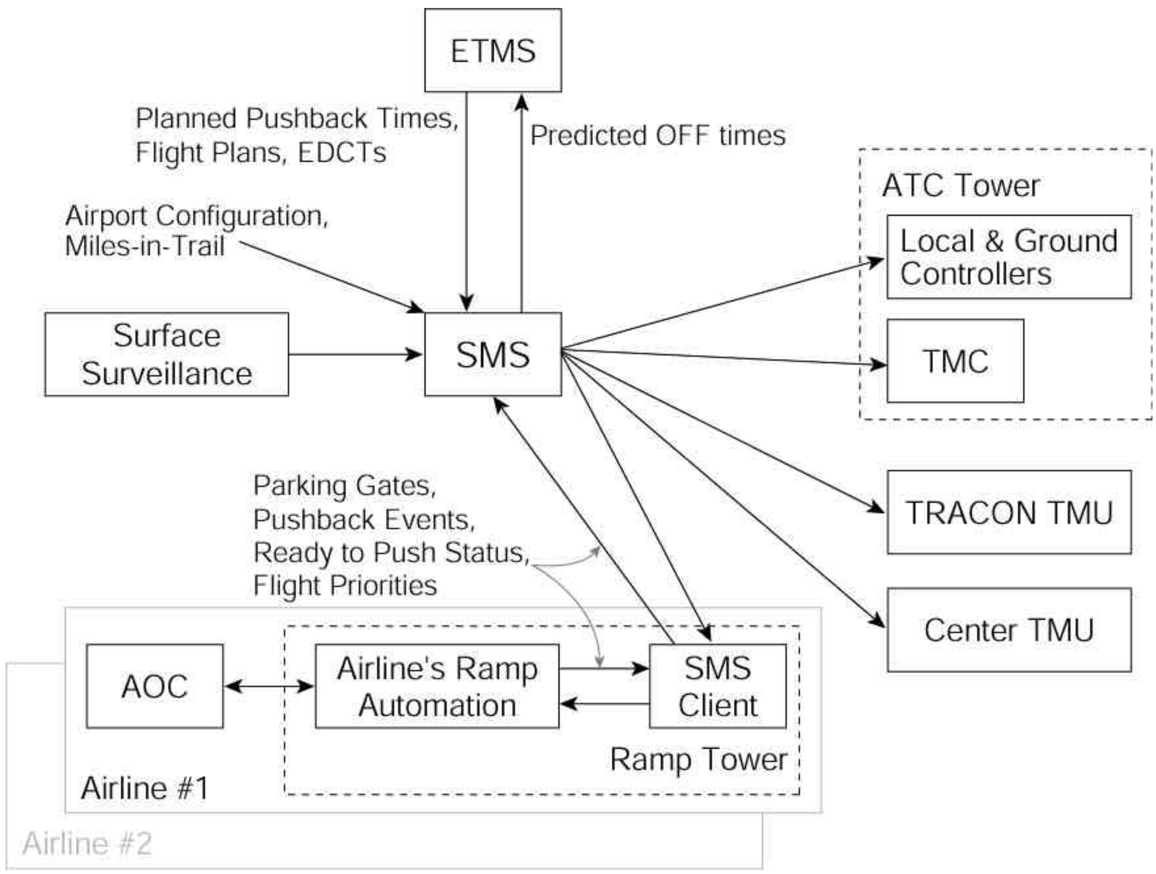
5. **Concept** for a New or Modified System

## 5.1 Background, Objectives, and Scope

[The following Background is taken verbatim from Reference 15].

NASA, in conjunction with the FAA, is developing a suite of decision support tools to address surface management issues. SMS can provide both information (predicted traffic demand) and decision support (advisories) at various levels. Figure 3 illustrates the systems and users that will interact with the future SMS.

**Figure 3. SMS Data Interfaces**




SMS has the potential to directly support at least three of the seven solutions listed by the FAA's OEP for increasing terminal throughput. These solutions include coordination for efficient surface movement, enhanced surface situational awareness, and the filling of gaps in arrival and departure streams. SMS can provide information and decision support for more accurate and timely controller and airline decisions. For example, SMS can support decisions regarding the surface movement of aircraft, runway balancing, and gate management by providing users with a shared view of predicted information regarding the future traffic demand on the airport surface.

Increases in capacity and efficiency are likely to be realized through better controller decision-making, thus leading to better management of aircraft on the airport surface.

By providing users with increased accuracy in surface traffic demand predictions of traffic on the airport surface, SMS can help to reduce delays and increase throughput. Providing multiple users (ramp control, AOC, and ATCT controllers) with predictive information of the future traffic demand at an airport can also benefit users by supporting effective tactical and strategic planning, reducing controller workload through information integration, and providing a shared view of the traffic situation for all users.

## 5.2 Operational Policies and Constraints

The operational policies and constraints relevant to the present traffic management system are contained in References 11 and 12:

- *FAA Order 7210.3S, Facility Operation and Administration*
- *FAA Order 7110.65N, Air Traffic Control*

These operational policies and constraints will have to be modified to accommodate SMS operations that are described in the following sections.

## 5.3 Description of the New or Modified System

[This description is taken verbatim from Reference 15].

**Computer Human Interface Description:** This section outlines the SMS features of Build 1. SMS provide controllers with information and decision support via several computer-human interfaces. These interfaces aid controllers by providing information, including aircraft specific information (e.g., aircraft identification (ID), aircraft type), flight plan information (first departure fix), current, and future location on the airport surface (predicted spot number, expected, or advised departure runway), delay information (departure delay, gate availability), and predicted arrival and departure demand (timelines and load graphs).

The research that is being done will focus on the information requirements for the various users, not necessarily the design of specific display features (e.g., should SMS show the departure fix in the ASDE-X data tag). Timelines and load graphs were found to be very helpful in displaying schedule and demand data and were accepted by TMCs during TMA development and testing. These features are now part of an FAA deployed system. Human factors data on the displays were collected and used during the SMS simulation activities and initial ramp tower demonstrations and the displays were found to be a useful way of presenting SMS information. Timelines and load graphs are not the only way to present this information and the FAA may come up with a different solution based on their information requirements.

**SMS Data Blocks**

In Human-in-the-Loop (HITL) simulations, data blocks were presented to controllers on both the timelines and an ASDE-like map display of the airport surface. Data blocks offered controllers aircraft-specific information. Information presented in the SMS data blocks varied based on different user information needs and whether the aircraft was an arrival or departure.

**SMS Timelines**

SMS timelines provided controllers with predicted departure and arrival times. Each timeline was referenced to either a runway threshold or spot area. A spot area is a group of spots for transferring control of aircraft between ATC and airlines associated with a particular airport terminal. In addition to predicted sequential information, SMS timelines present aircraft-specific information via data blocks.

**SMS Load Graphs**

**SMS load graphs provide aggregate information about predicted airport demand.**

**SMS Runway Advisories**

**These advisories are displayed to controllers in the data blocks on the timelines and map display. SMS runway advisories are presented when SMS algorithms calculated benefits in the reassignment of an aircraft to an alternate runway. Controllers can distinguish runway advisories from runway assignments by asterisks placed on either side of the advised runway change.**

**SMS Gate Availability**

The foundation of SMS is its capability to predict how future departure demand will play out on the surface. These predictions will be provided as products themselves, as discussed in the next section. Furthermore, the ability to predict how the state of the airport surface will evolve enables SMS to evaluate the effect of various traffic management decisions in advance of implementing them.

[The following description of SMS's Departure Situation Prediction Capabilities up to and including System Architecture is taken verbatim from Reference 3].

**Departure Situation Prediction Capabilities:** A primary function of SMS is to create shared awareness of the current and future departure situation among the ATCT, TRACON TMU, Center TMU, and air carriers by providing information about expected departure demand and how the surface situation will evolve under that demand. To achieve this, SMS will provide information, either using dedicated SMS displays or by adding the information onto the displays of other systems, to the ATCT and ramp towers, as well as, possibly, the TRACON and Center TMUs and the AOCs. Within the ATCT, SMS will provide information to some or all of: the Local Controllers, Ground Controllers, Clearance Delivery/Flight Data Controller, and Supervisors/TMC. It is anticipated that capabilities will be deployed to FAA facilities and data feeds would be provided to airlines. The tower is the primary FAA focus, followed by the TRACON and the ARTCC.

**Near-Term Departure Demand**

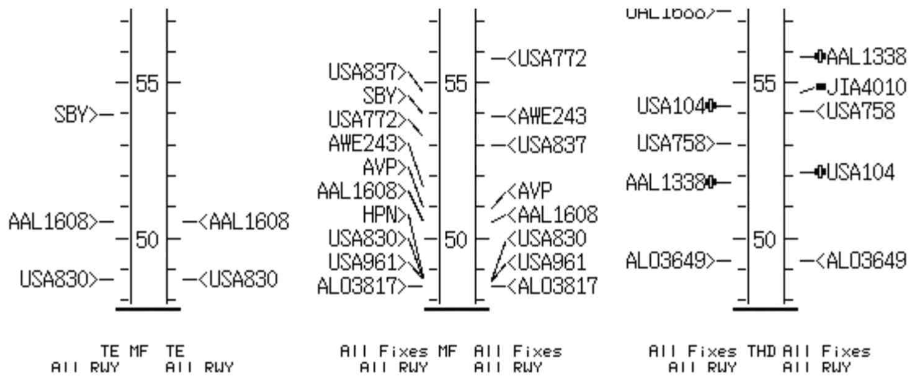
SMS will provide both near-term and longer-horizon predictions of the departure situation. Near-term predictions will consist of, for example, the expected queue lengths at each runway for the next 15 to 30 minutes, the predicted takeoff sequence, and the resulting takeoff times and delays for individual aircraft. To predict the state of the surface over the next 15 to 30 minutes, depending on taxi-out times, SMS will use real-time surface surveillance information that includes aircraft identity, from ASDE-X or another similarly capable system, and a surface trajectory synthesis algorithm that accurately predicts the movement of aircraft on the airport surface. To accurately model the evolution of the surface situation, the automation must consider how controllers assign departure runways and taxi routes, how they sequence departures, how they use multiple queues to feed departure runways, and how arrival traffic affects departures. The automation must also consider inter-departure restrictions, including downstream constraints.

Developing displays that ATCT controllers and supervisors/TMCs accept and use will be a major challenge. This is particularly true of local and ground controllers who are accustomed to making decisions based on flight strips and their out the window view. The TMA Timeline Graphical User Interface (TGUI) is a useful framework in which to conceptualize the type of information that SMS will be able to provide. Timelines may be referenced to any physical point, including runways, spots, and departure fixes. Figure 4 shows TMA timelines; the left two show when aircraft will cross the arrival meter fixes and the right most shows when aircraft will reach the runway threshold. The information SMS will present will depend on who will use it and what task it will aid. For example, a timeline referenced to the departure runways showing the predicted departure times and an advised sequence is being studied as a display for the local controller. A timeline referenced to the hand-off spots is being considered to aid the ground controller in the task of accepting aircraft from ramp hand-off spots in an efficient and user-preferred sequence.

Timelines offer several other display dimensions to encode additional information. Timelines are able to provide trend information “at a glance” by color coding the aircraft. SMS may use color to distinguish to which departure gate a flight is filed. Additional information, such as the aircraft’s departure fix, will be included in the data block. Bars can be added to aircraft data tags to show the periods of time that the aircraft will occupy the runway (or other constrained resource). In this way, timelines are capable of depicting the separation between arrival, departure, and crossing operations on a runway.

By providing information which is not currently available, SMS is anticipated to improve controllers’ ability to manage surface traffic efficiently and maximize departure throughput. Moreover, having a common awareness of the near-term departure situation may facilitate the ATCT and air carriers in collaboratively managing departure queues and surface movements (e.g., manually sequencing departures to improve departure throughput). Takeoff time predictions may benefit air carrier decision making. Information about current and predicted departure queues displayed in the TRACON TMU may allow better coordination of runway use without explicit communication between the ATCT and TRACON. For example, the TRACON would know when a departure queue exists at a runway and could stop sending arrivals to that runway, without the ATCT Supervisor/TMC needing to call the TRACON TMU. Similarly, if the TRACON TMU had information about queues trying to cross an arrival runway, the TRACON could adjust the gaps between arrivals to facilitate crossing without the ATCT needing to call to ask the TRACON to slow the arrival rate. Finally, the algorithmic and display developments required to provide this near-term departure information are a necessary step toward SMS providing advisories to help with the management of surface and departure operations.

**Figure 4. TMA Timeline Display of Predicted and Scheduled Arrival Times**




Given parking gate information, SMS will also calculate accurate taxi time estimates for arrivals. Better predictions of IN (i.e., gate arrival) times will improve air carrier decision making about gate and ground resource management. Where CTAS (TMA or FAST) is available, SMS will use the CTAS arrival time estimates. Otherwise, SMS will use radar surveillance to calculate arrival time predictions.

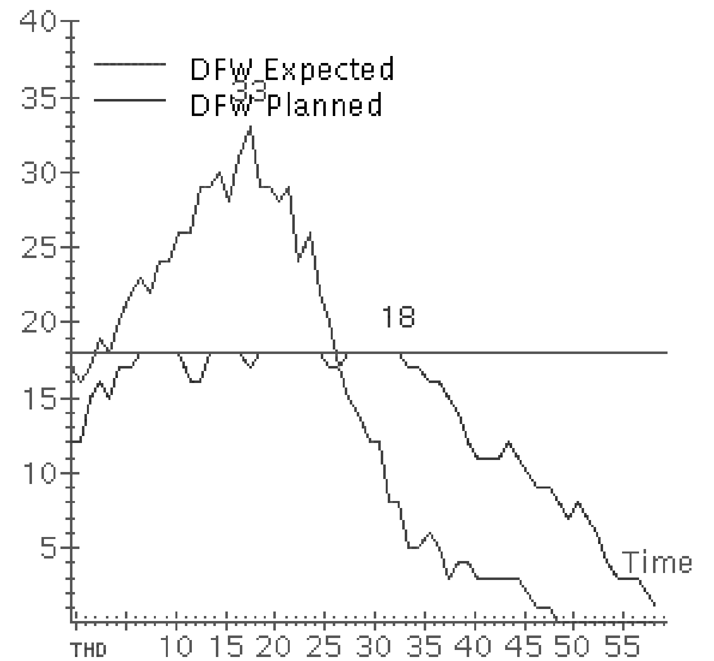
Ground controllers use knowledge of an aircraft's parking gate (or the hand-off spot at which the aircraft transitions from ATCT to ramp tower control) to plan a taxi route for the aircraft. In addition, TRACON Arrival controllers sometimes use this information for arrival runway assignments. SMS will convey this information with less workload than is currently required. Currently, the ramp tower (or the air carrier's station at airports where the air carrier does not have a ramp tower) tells pilots their gate or spot when they call "in range." At DFW, for example, the pilot then relays this information to the ground controller. During night operations at MEM, the pilot relays this information to the TRACON Arrival controller, who enters it into the Automated Radar Terminal System (ARTS) scratch pad. The ground controller then copies the ramp entry spot from the Digital Bright Radar Indicator Equipment (DBRITE – the repeater of the TRACON radar display located in the ATCT). SMS, which will receive the arrival gate from the air carrier, will provide this, as well as a recommended spot, to the ATCT earlier and with less radio communication.

**Longer - Horizon Departure Demand**

SMS will also forecast aggregate demand (i.e., total number of aircraft in a period of time, without identifying individual flights) for each runway, or other constrained resource, over a longer time horizon, similar to that over which TMA predicts and manages arrival demand. To predict departure demand further in advance (i.e., prior to aircraft pushback), SMS will use airline-provided information about when each aircraft will want to push back. By providing information about the future departure demand, SMS will allow the ATCT, air carriers, TRACON, and Center to coordinate traffic management decisions (e.g., what restrictions to place on departures and, in concert with information about future arrival demand, arrival-departure tradeoffs) based on a common situation awareness. SMS-provided information about future departure demand is expected to be most helpful during irregular operations, when controllers cannot use knowledge of daily schedules gained through experience to predict the timing of future demand.

The TMA Load Graph, shown in Figure 5, is useful for describing the type of information that SMS will provide. Load graphs are capable of showing both predicted (i.e., without traffic management intervention) and scheduled profiles. In addition, load graphs can show multiple predictions for alternative traffic management decisions, to provide a "what if" capability. Like the near-term predictions, aggregate demand forecasts may be referenced to a variety of constrained resources other than the runways, such as departure fixes or parking gates/spots. What aggregate information will be presented will depend on who will use it and what task it will aid, and will be determined as the research progresses. As examples, SMS will display load graphs of the future demand for each departure gate to the ground controller and Supervisor/TMC to aid runway balancing decisions. SMS will also display load graphs of the delay at each runway under the current and alternative departure scenarios.

**Figure 5. TMA Load Graph Display of Aggregate Demand**




## Departure Planning Concepts

SMS users may not have the necessary information or time to plan beyond immediate aircraft movements, especially during busy periods. The ability to predict the future departure situation enables SMS to aid users by advising how to manage some aspects of surface operations to best achieve strategic goals. SMS's departure planning attempts to increase airport throughput (i.e., peak capacity rate), increase the efficiency of surface operations (i.e., minimize the cost of unavoidable delays and their environmental impact), and improve user flexibility (i.e., minimize the impact of delays on air carrier business objectives), without increasing user workload. SMS will continually update its advisories to react to the current situation and controller actions and will be collaborative between the ATCT and the air carriers. Exactly what information or advisories will be displayed to which controllers or air carrier personnel will be determined as part of the research; the following describes the initial research focus of Build 1.

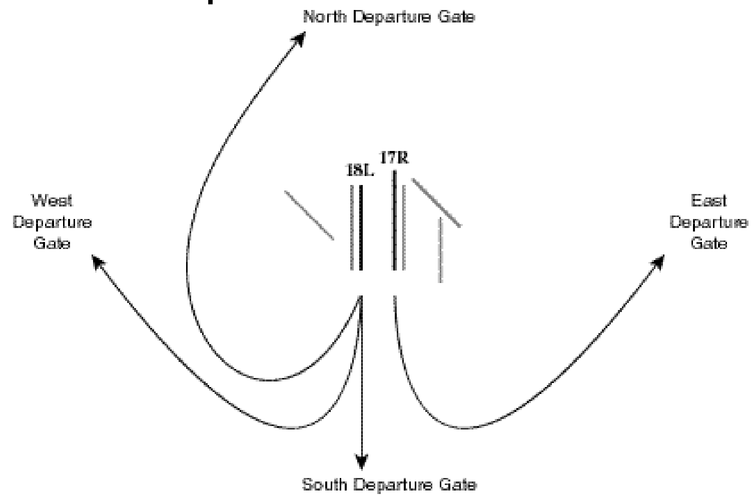
SMS will plan and recommend a departure sequence for each runway that maximizes runway throughput subject to wake vortex and downstream traffic management restrictions. An additional objective of departure sequencing will be to incorporate air carrier priorities to enhance user flexibility without compromising fairness or throughput. At some airports, such as DFW, the taxiway geometry allows the ATCT to construct efficient departure sequences after aircraft enter the active movement area. However, at other airports, the ATCT has limited ability to sequence departures once aircraft have pushed back from their gates. For example, when Philadelphia airport (PHL) operates in an east flow configuration, the ATCT has almost no opportunity to sequence departures off Runway 9L, since the US Airways ramp tower controls taxiway Juliet almost to the departure end of the runway and the ATCT does not know which flights are in this queue. The ATCT controls parallel taxiway Kilo which also feeds 9L. In this case, SMS could help the ramp tower sequence departures on taxiway Juliet, and help the ramp tower and ATCT coordinate which aircraft should queue on taxiway Juliet and which should be handed off to the ATCT (and at which spot) to queue on Kilo. Note that to provide many of the planned capabilities, SMS will need ASDE-X to provide surveillance of the ramp areas (which the FAA has not currently specified as a requirement in the ASDE-X program) as well as the active movement area.

SMS will also help manage Approval Request (APREQ) flights. When calling the Departure controller for a release time for a flight, the ATCT needs to know when the flight would be able to reach the departure runway. SMS will predict the earliest departure time, accounting for surface traffic, and then advise queue assignments (where multiple queues feed a runway) and a departure sequence to meet the assigned APREQ time window. SMS will similarly support controllers in meeting EDCTs for flights with ground holds.

**Departure Runway Balancing**

SMS will provide decision support for runway assignment decisions, with the goal of increasing airport capacity by maintaining balanced departure runways. Removing a few aircraft from a queue (and reassigning them to a different runway) at the beginning of a departure rush can reduce the delays incurred by every subsequent departure. Current procedures assign departures to a runway according to a one-to-one mapping from departure fixes to departure runways. The purpose of these runway assignment rules is to assure that the airborne trajectories of aircraft that takeoff from different runways do not cross. The different mappings of departure fixes to departure runways are referred to as departure scenarios. For example, Figure 6 shows the departure scenario DFW typically uses during an eastbound push in south flow operations. The ATCT selects the departure scenario to balance the demand on each of multiple departure runways.

**Figure 6. DFW Departure Scenario for an Eastbound Push**




SMS will evaluate two approaches for aiding departure runway balancing: supporting the selection of the departure scenario schedule and advising runway assignments for specific flights that are exceptions to the departure scenario. SMS will support the ATCT's selection of the departure scenario by providing information about the demand, as a function of time, for each of the departure fixes. This information is not currently available. Although currently controllers can scan all of the flight strips for the proposed flights to determine the demand for each departure fix, the time at which each flight will want to depart is not known reliably. During normal operations, controllers know approximately when each flight departs from experience. However, during irregular operations, flights will not depart at their typical times. SMS-provided information would allow the ATCT to select an efficient departure scenario and to plan when to change the scenario. In this way, the departure scenario may be adjusted more frequently, and the timing of changes may better match the time-varying demand. Alternatively, SMS will consider calculating and advising an optimal schedule for the departure scenario.

The flight-specific runway advisory function will search to determine whether one or two departure runway assignments (per rush) that are exceptions to the current departure scenario could provide a significant reduction in total departure delays. Since these runway assignments would violate the active departure scenario, which procedurally assures that there will be no airborne conflicts between departures off different runways, the search for beneficial alternate runway assignments is further constrained by the requirement that the suggested runway assignments cannot cause airborne conflicts. Airborne departure conflicts would represent a safety concern and create high controller workload. To ensure conflict-free departure trajectories, SMS will perform a conflict probe to ensure that the advised departure sequence (and resulting departure times) and the departure runways do not result in a conflict in departure airspace. In Build 1, this conflict probe will be the application of the procedural rules that are currently used to assure that flight paths do not cross.

Note that controllers currently do this manually when workload permits. Although the aircraft will be flying to the same departure fix as is in its flight plan, since the aircraft will be departing off a different runway, the ATCT must coordinate with the affected Departure controllers to assure that airborne separation will be maintainable with acceptable workload. The aircraft will be displayed on the radar scope of the Departure controller assigned to the filed departure fix, but will be coming off a different runway than the other aircraft that controller handles. This is most easily done at the beginning of a departure push, before the airspace gets busy. By automating the search for feasible and beneficial runway assignments that are exceptions to the current departure scenario, and by simplifying the necessary coordination, SMS may allow more frequent use of the technique during busy periods, when it will have the most benefit.

Alternatively, SMS will recommend changing a flight's flight plan to use a different departure fix so that the flight would be assigned to a different departure runway without violating the rules of the active departure scenario. In this case, the aircraft would rejoin its original route in Center airspace. The purpose of using an alternate departure runway for a particular flight could be either to help balance the departure runways or to help that flight takeoff earlier. Due to its effect on fuel requirements or business objectives, the flight's dispatcher/AOC may need to approve a flight plan change. Therefore, SMS will recommend the departure fix change to the AOC or ramp tower, in accordance with Coded Departure Routes which will facilitate the communication and coordination of departure routes. Rather than advising a flight plan change for a particular flight, displaying the predicted delays for each departure fix would allow the AOC to evaluate which flight to reroute. Depending on the timing, the associated flight strip may need to be returned to the Clearance Delivery (CD) controller from the ground controller's bay of flight strips. Currently, the ATCT will occasionally initiate flight plan changes to balance departure runways. At DFW, for example, this is typically done by the CD controller when issuing the Pre-departure Clearance (PDC). However, it may be done after the aircraft has pushed back and is waiting at a spot. SMS will automate the search for candidate flights and the necessary coordination.

**<u>Arrival-Departure Tradeoffs</u>**

At airports where arrival and departure capacities are interdependent, due to interactions between the two types of operations, arrival and departure management must be interoperable. TMA-provided information about future arrival demand, in conjunction with the shared awareness of future departure demand that SMS will create, may enable the ATCT, TRACON, and Center to coordinate traffic management decisions, such as arrival-departure tradeoffs, with less workload and better use of limited resources. Additional efficiencies may be achieved by adjusting the arrival and departure rates more dynamically to track the time-varying demands. Note that if TMA is not available to provide flight arrival time estimates, SMS can generate estimated arrival times, although SMS's predictions are expected to be less accurate than TMA's.

In addition to providing raw information, SMS will advise a schedule of coordinated arrival and departure capacities that match the time-varying demands for the two types of operations. SMS is able to include considerations such as the potential for surface gridlock if arrivals are favored when departures are late. In this case, for example, when arrival gates are not available, SMS would advise favoring departures. A trial-planning capability, in which SMS will predict the delays that would result from a traffic management decision that is being considered, is a possible future feature of SMS.

To achieve the planned arrival-departure mixture, the Center TMU can manually adjust the airport acceptance rate (AAR) to which TMA schedules arrivals, and the ATCT will manage departures, opportunistically using available departure capacity. However, to achieve the planned departure rate, the TRACON may need to impose additional constraints on arrivals to create gaps in the traffic stream in which departures efficiently fit. To what extent individual aircraft must be managed (i.e., tactical arrival-departure interoperability) to achieve the arrival and departure rates (i.e., strategic arrival-departure interoperability) will be addressed in the research. This capability will not be included in the Build 1 of SMS that will be demonstrated at a field site.

## Queue Length Management

Managing the rate at which aircraft enter the taxiway system has the potential to reduce the environmental and operating costs associated with long departure queues while maintaining maximum departure throughput. By maintaining shorter runway queues, aircraft are running their engines for less time on the surface. SMS may help the ATCT and ramp tower to collaboratively manage departure queue lengths by advising aircraft pushback or taxi-start times. Pushback management must be done collaboratively with the air carriers so that the solution allows the air carriers to manage their gates, and fairly so that gate-held flights do not lose their place in the virtual departure queue. Eventually, SMS may fairly allocate departure capacity to air carriers, much as the Collaborative Decision Making (CDM) Flight Schedule Monitor (FSM) tool allocates an airport's arrival capacity when ground holds are imposed on departures to that airport. In this case, the air carriers could make decisions about which departure to operate in each slot to best achieve their business objectives.

Queue length management also has application during de-icing operations. To determine when to start de-icing a flight, the departure delay that the flight will incur must be estimated. SMS would predict the queue lengths and delays both at the runway and the de-icing operation. To do this, SMS would need the airport authority, which is responsible for clearing the runways, to provide information about when each runway will be closed.

## System Architecture

Figure 7 shows the system architecture for SMS, with shaded boxes representing elements that will be part of Build 1 of SMS and outlined boxes representing possible future deployment locations. SMS displays will present information and advisories in the ATCT and the air carrier's ramp towers. In addition, SMS displays may operate in the TRACON TMU, Center TMU, and AOCs. The physical location of the SMS display in each tower will be determined as part of the research.

SMS is being designed to use real-time location and identity information about aircraft on the airport surface, although some SMS capabilities will function without this input. The ASDE-X system, currently being developed by the FAA, will combine either an existing ASDE-3 or a new X-band primary radar, an Airport Traffic Information Display System (ATIDS, which is a transponder-based multilateration surveillance system), Automatic Dependent Surveillance – Broadcast (ADS-B) transmissions from aircraft, and ARTS information to produce a coherent picture of aircraft moving on the airport surface. Some of SMS's functions will require that ASDE-X coverage include the ramp areas. NASA will test SMS at Memphis, where the FAA's Safe Flight 21 program has developed a prototype surface surveillance system which is functionally equivalent to ASDE-X. It combines ARTS, ADS-B and multilateration to achieve comprehensive coverage on the airport surface. Note that the Safe Flight 21 system at Memphis has been enhanced to include coverage of the ramp areas. SMS may also get limited ARTS airborne surveillance information from the Safe Flight 21 system which it will use in the prediction of landing times for the arrivals.

SMS will receive flight plan information, as well as surveillance information for arrivals outside the terminal area, from the Enhanced Traffic Management System (ETMS). SMS will receive the air carrier's planned departure times for each flight from the Aggregate Demand List (ADL), an element of CDM hosted as part of ETMS. The sufficiency of this information for this application is not yet known. This research will help identify the requirements for the accuracy of knowledge about departure demand to perform various levels of departure planning. Ramp towers currently have better knowledge about when each flight will want to push back than the AOCs. The SMS project will work with the air carriers to encourage them to communicate their best available intent information to the AOC systems that provide demand predictions into the ADL. This approach avoids the need to interface to every air carrier's ramp tower automation system.

To predict taxi-in times as well as surface conflicts between arrivals and departures, SMS will need to know at what gates the arrivals will be parking. If this information cannot be added to the ADL data stream, then, as an interim approach, SMS will get it from the ramp towers, either through manual entries or connections to the air cariers' automation systems. SMS will also incorporate air carrier priorities in its departure planning; these preferences will either be inferred from the air carrier's schedule or entered manually by the ramp tower or AOC.

To correctly model inter-departure times and plan efficient sequences, SMS must know what downstream restrictions are in effect. The National Log Program will provide miles-in-trail restrictions. EDCTs for aircraft affected by ground holds are available from ETMS. The current airport configuration, planned configuration changes, and APREQ times are the only information that the ATCT controllers will be required to enter.

**<u>Functional Flow</u>**

Figure 8 is an expansion of Figure 7, showing the currently planned SMS elements (shaded) as well as the future ones. All of the known inputs and outputs of the SMS are shown, as well as four of the required functions (Surface Trajectory Synthesis, Construct Departure Queues, Trial Planning, and Conflict Prediction). Shown within the central SMS box are all of the parameters that SMS will eventually calculate and send to the various elements shown on the diagram. The exact flow of information, as SMS evolves, is not known at this time. This diagram will be updated as SMS plans and designs become firmer.

Figure 7. SMS System Architecture

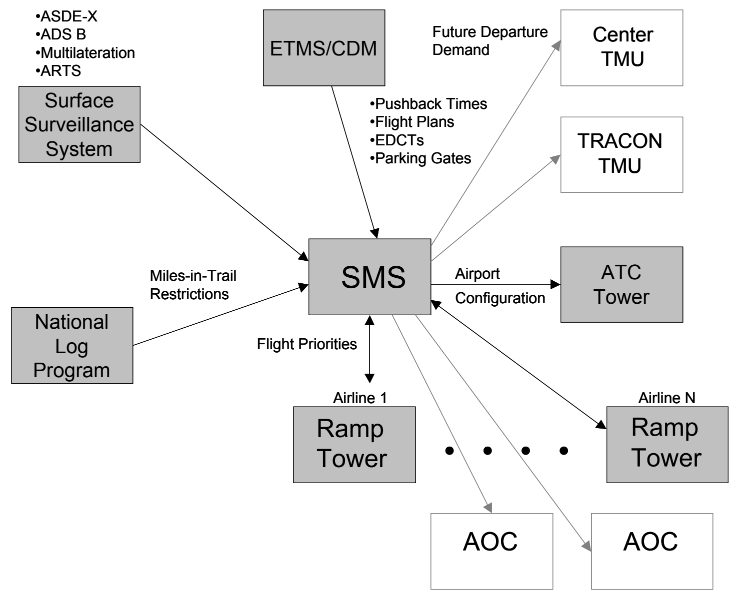
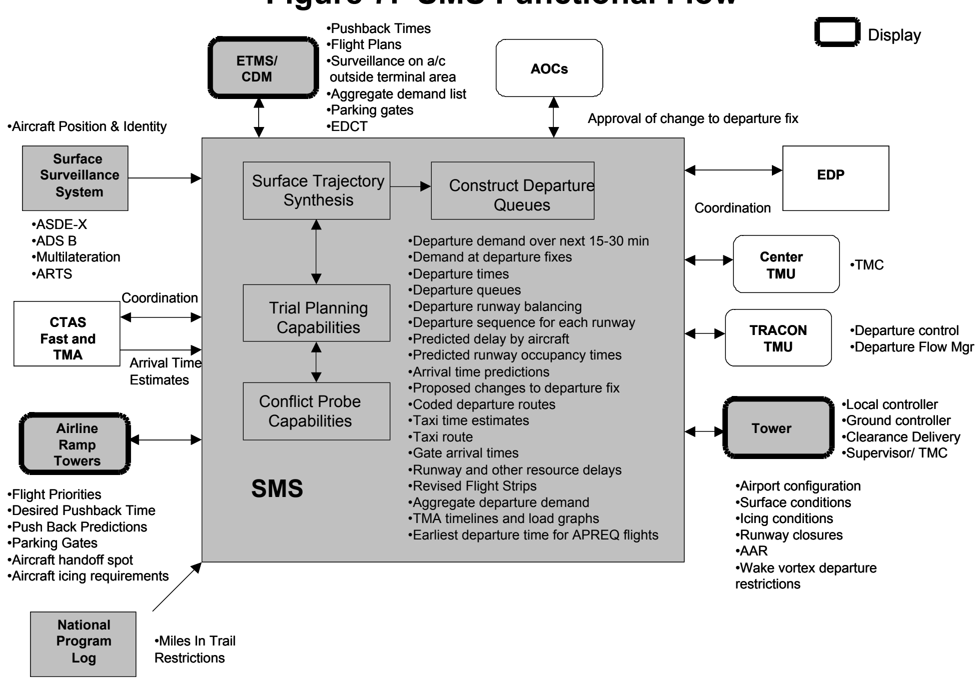



Figure 7. SMS Functional Flow




## 5.4 Users/Affected Personnel

Table 4 indicates the SMS users and affected personnel. A description of how each user is impacted by SMS can be found in Section 6, Operational Scenarios.

**Table 4. Users or Personnel Involved in SMS Operations**

| Users or Involved Personnel | SMS Operations |
|---|---|
| Traffic Management Specialist at ATSCSS | ✓* |
| Air Traffic Control Supervisor (ATCS) | |
| Supervisory Traffic Management Coordinator-in-Charge (STMCIC) | |
| Operations Supervisors (OS) | |
| Traffic Management Coordinator (TMC) | ✓* |
| En Route Radar Position – R controller | |
| En Route Radar Associate (RA) – D controller | |
| En Route Radar Coordinator (RC) | |
| En Route Radar Flight Data (FD) Position | |
| En Route Non Radar (NR) Position | |
| Terminal Radar Position – R controller | |
| Terminal Radar Associate (RA) – D controller | |
| Terminal Radar Coordinator (RC) | |
| Terminal Radar Flight Data (FD) Position | |
| Terminal Non Radar (NR) Position | |
| Tower Local Controller (LC) | ✓ |
| Tower Ground Controller (GC) | ✓ |
| Tower Associate | |
| Tower Traffic Management Coordinator (TMC) | ✓ |
| Tower Flight Data Position | ✓ |
| Tower Clearance Delivery/Flight Data Position | ✓ |
| Flight Service Station Specialist (FSSS) | |
| Airline Ramp Tower | ✓ |
| Airline Operations Center (AOC) | ✓* |
| Pilot or Flight Crew (FC) | ✓ |

✓* Future version of SMS beyond Build 1

## 6. Operational Scenarios

The following discussion will illustrate the nominal operation of SMS. Other conditions such as rare-nominal and failure are not defined for SMS at this time.

The normal, or nominal, condition for SMS is where all air and ground systems function as expected under normal conditions, traffic is in a steady state condition in terms of approach airspace used, routes and zones are not blocked by weather cells. Changing runways is considered to be a normally occurring condition.

[The following description of nominal operation of SMS is extracted verbatim from Reference 2].

**For the ATCT Traffic Management Coordinator:**

The traffic management tool component of SMS is used by Traffic Management Coordinators in the ATCT, TRACON, and ARTCC, as well as ramp tower supervisors and air carrier AOCs.

**Departure Scenario Selection**

SMS affects departure runway assignments through three mechanisms: (1) supporting the selection of the departure scenario and the schedule for changing the scenario: (2) supporting runway assignments for specific flights that are exceptions to the active departure scenario; and (3) supporting flight plan changes that will adjust runway assignments. This section will discuss departure scenario selection (item 1). The second mechanism is discussed in the section on Ground controller products; the third mechanism is discussed in the section on SMS capabilities for the air carrier's AOC.

SMS supports the ATCT TMC's selection of the departure scenario first by providing information about the unconstrained demand for each of the departure fixes/gates as a function of time. The *unconstrained* traffic count is the number of aircraft that want to use the resources during the time interval. In contrast, the *constrained* (or scheduled) traffic count is the number of aircraft that will use the resource during a time interval, accounting for required separation and controller workload limitations.

During normal operations, controllers know approximately when each flight departs from experience. However, during irregular operations, flights will not depart at their typical times. Although controllers can scan the Flight Progress Strips (FPSs) for all of the proposed flights to estimate the demand for each departure fix, the time at which each flight will want to depart is not currently known reliably, since air carrier decisions to adjust their schedules may not be reflected in the times printed on the FPSs.

SMS also predicts the queues and delays that will exist at each runway as a result of the demand. SMS can calculate multiple predictions for alternative traffic management decisions, to provide a "what if" capability.

In addition to aggregate forecasts (i.e., total number of aircraft in a period of time, without identifying individual flights), SMS predicts the movement of individual aircraft.

**For the TRACON and ARTCC TMCs:**

**Tradeoff of Arrival and Departure Rates**

At airports where arrival and departure capacities are interdependent due to interactions between the two types of operations, arrival and departure management must be interoperable. SMS provides the TMCs in the ATCT, TRACON, and ARTCC with a common picture of both the unconstrained future arrival and departure demands as well as the constrained traffic counts and delays that are predicted to result after necessary separations are applied. This shared awareness allows the TMCs to coordinate traffic management decision, for example trading off the arrival and departure capacities in a way that is appropriate for the competing demands, resulting in more efficient use of the limited resource. Additionally, this information may support adjusting the arrival and departure rates more dynamically to track time-varying demand.

SMS also offers a trial-planning capability, in which SMS predicts the arrival and departure delays that would result from a traffic management decision that is being considered. Before committing to a possible traffic management decision, the TMC can see what the timelines and load graphs of arrival and departure delays would look like. Finally, SMS can advise a schedule of coordinated arrival and departure capacities that best match the time-varying demands for the type of operations.

**Coordination of Arrival and Departure Runway Use**

SMS provides information about current and predicted departure queues in the TRACON TMU to enable better coordination of the use of runways for arrivals and departures, without explicit communication between the ATCT and TRACON TMCs. A display shows when a departure queue does or will exist at a runway, without the ATCT needing to call, to help the TRACON TMC make decisions about moving arrivals to a different runway or slowing arrivals.

**APREQ Release Times**

SMS also helps manage APREQ flights. Currently, the ATCT (often the Ground controller when the aircraft calls for pushback or reaches the hand-off spot) calls the ARTCC TMU for a release time. The ATCT tells the ARTCC TMC the earliest time the aircraft could be at the runway, and the TMC estimates at what time the flight should takeoff to fit into an appropriate gap in the traffic stream into which the flight must be merged. SMS supports this process, first, by predicting the earliest time at which the flight would be able to reach the departure runway, accounting for surface traffic. SMS provides a table of the earliest possible departure time for each APREQ flight, accounting for surface traffic, directly to the ARTCC TMC. When convenient, rather than when the ATCT calls, the ARTCC TMC can plan a release time, enter it into SMS, and SMS will relay the release time to the ATCT without the ATCT having to call. If a flight’s release time is entered into SMS, either by the ARTCC TMC or by the ATCT if the current voice communication with the ARTCC TMC is maintained, SMS will help the Ground and Local controllers meet this restriction, similar to the way SMS supports meeting EDCTs and hold-over limits during deicing.

**For the Air Carrier Ramp Tower:**

**Ground Resource Planning**

SMS provides estimates of when each arrival aircraft will reach its spot and parking gate, using timelines and tables. SMS using parking gate information to estimate the taxi time for each arrival. Better gate arrival time predictions improve air carrier decision making about gate and ground resource management, as well as whether or not to hold departures to allow late arrivals to make connections. Where CTAS is available, SMS will use the CTAS estimates of touchdown times; otherwise, SMS predicts landing times itself.

**Departure Planning**

SMS helps the ramp supervisor and controllers manage pushback times. SMS provides information about the current downstream restrictions (e.g., MIT) that affect each flight and the delays that will be experienced at each departure fix or runway. SMS plots how the departure queue length will evolve: (1) if no additional aircraft pushback; and (2) assuming aircraft continue to pushback at their scheduled times. The ramp controller can use this information, for example to hold pushing back a flight that will be delayed at its runway to allow other flights out of the ramp first. As long as a queue exists at the runway, no departure capacity is wasted. Therefore, the ramp could hold other departures so that when a late departure is ready, it will wait behind a shorter queue.

**Arrival/Departure Coordination**

Predictions of when arrivals will reach their gates will help ramp controllers make decisions about gate availability. For example, the ramp controller will know how long a departure can wait to push back before an arrival will be delayed. If an arrival is expected to reach a gate before a departure occupying that gate will be ready to push back, the ramp controller can reassign the arrival to a different gate or request that the ATCT hold the arrival out until the gate is available. ATCT ground controllers desire to know earlier in an arrival's taxi whether the ramp tower will accept the aircraft or ask the ATCT to keep the aircraft. SMS allows the ramp tower to enter when an arrival's gate is unavailable, which is relayed to the ATCT.

**At some airports (e.g., Atlanta's Hartsfield International Airport), a narrow alley separates terminal buildings, creating the opportunity for congestion between arrivals and departures. If an arrival needs to park at a gate past where a departure has pushed back, the arrival must not enter the alley before the departure has exited. SMS-provided information about when arrivals reach spots will help the ramp tower make decisions about holding a push back to avoid gridlock (i.e., the departure needing to be tugged back up to the gate) or requesting the ATCT hold the arrival to allow a higher priority departure to get out first.**

**Handle Departure Time Restrictions**

SMS aids the ramp tower in managing flights to meet departure time restrictions. During de-icing operations, SMS allows the ramp controller to enter the maximum hold-over time for each aircraft, which is automatically communicated to the ATCT so that the controllers know by when aircraft must depart to avoid needing to be de-iced again.

Furthermore, SMS information helps the ramp tower manage the length of the queues at the runways and de-icing stations. To help the ramp tower determine when to start de-icing a flight, SMS estimates the departure delay that the flight will incur after de-icing. SMS predicts the queue lengths and delays both at the runway and the de-icing operations.

**Sequence Departures**

SMS allows the ramp supervisor to enter the relative priority of each departure. SMS can display this information to the ground and local controllers, to be included in their decision making as appropriate.

At some airports, such as DFW, the taxiway geometry allows the ATCT to construct efficient departure sequences after aircraft enter the active movement area. However, the taxiway configuration at other airports limits the ATCT's ability to sequence departures once aircraft have pushed back from their gates or entered the active movement area. In this case, SMS will provide departure sequence advisories to the ramp tower controllers that avoid consecutive flights to the same fix, for example, so that the ATCT can construct a departure sequence that efficiently uses the runways.

**For the Airline Operations Center:**

**Flight Plan Changes**

SMS considers whether changing a flight plan for a particular flight would be beneficial to avoid delays at a runway or departure fix, depending on which is the constrained resource. By changing the departure fix, a flight plan change can result in a different departure runway being used without violating the rules of the active departure scenario. The departure fix may also be changed where the same runway would be used to avoid either high demand for that fix or downstream restrictions (e.g., MIT) on that fix. SMS considers the impact on taxi distance and flight time when calculating the benefit of a flight plan amendment. Currently, the ATCT will occasionally initiate flight plan changes. At DFW, for example, this is typically done by the Clearance Delivery (CD) controller when issuing the pre-departure clearance. However, it may be done after the aircraft has pushed back and is waiting at a spot, in which case the ground controller instructs the pilot to contact CD for a new route, and a new flight strip is generated in the tower. SMS automates the search for candidate flights and provides supporting information.

Due to its effect on fuel requirements or business objectives, the flight's dispatcher/AOC may need to approve a flight plan change. In accordance with the existing Coded Departure Route (CDR) program, which facilitates the communication and coordination of alternate departure routes, the flight's dispatcher can evaluate CDRs (possibly recommended by SMS) and conform that the aircraft has the appropriate fuel. The dispatcher would do this either when initially filing the flight plan or at some later time, but before the pilot contacts the CD controller. The dispatcher enters the approved CDRs into SMS and informs the pilot which CDRs may be accepted; SMS indicates to the ATCT which CDRs are available for that flight.

The purpose of changing the departure runway for a particular flight could be either to help balance the departure runways or to help that particular high-priority flight take off earlier. Either the ATCT or the AOC can initiate use of a CDR. SMS provides information about the predicted delays for each departure fix and runway to enable the ATCT (TMC or CD controller) or AOC (dispatcher or ATC coordinator) to evaluate which flights to reroute. The AOC would initiate a flight plan change either by calling the TMC or instructing the pilot to make the request to the CD controller. In addition, SMS can advise the ATCT TMC which flights should be routed and which of the available CDRs for those flights should be selected.

**For the Air Traffic Control System Command Center:**

**Data to the Enhanced Traffic Management System (ETMS)**

The NAS information tool component of SMS provides data to ETMS to support the ATCSCC and to be further disseminated to NAS users. There currently exists a large amount of uncertainty in the Traffic Flow Management (TFM) system regarding the time at which flights will depart from their origin airport. This uncertainty accounts for a significant portion of the error in the ETMS Sector Monitor Alert capability and in the Flight Schedule Monitor (FSM) too. Other FAA projects are currently studying using real-time surveillance data to detect pushback and takeoff events, and provide these surveillance-derived OUT and OFF times to ETMS. In addition, the TFM system needs accurate predictions of when each flight will takeoff. Pushback detection can be used to improve takeoff time prediction, although using historical average of taxi time introduces substantial uncertainty. By modeling the movement of the traffic actually on the surface at the time, and thereby providing accurate taxi time estimate, SMS can further improve takeoff time predictions. SMS-predicted takeoff times are communicated back to the ETMS system for use in the Monitor Alert calculations and in the FSM too, transparently improving all of the predictions and products that are based on predicted takeoff time. Although some interface protocols already exist to allow airlines to submit updated predictions of a flight's takeoff time, some modifications in the ETMS system maybe required to accept the SMS data.

**For the Air Traffic Control Tower Ground Controller:**

**Flight Specific Information**

SMS uses a map display to provide a variety of flight-specific information to the ground and local controllers. SMS research has shown that the ground and local controllers have a strong preference for all necessary information being available from a single display. Therefore, eventually any information that SMS provides to the local and ground controllers will likely need to be incorporated into the ASDE-X display or the STARS tower display. Since this integration is beyond the scope of the current NASA project, the SMS research is using a separate map display to evaluate what information content is useful. This SMS map display resembles the ASDE-X display, but does not fully conform to the FAA's Visual Specification for Airport Surface Applications.

**Gate/Spot Information**

The gate/spot information appears in the second line of the arrival data block on the map display. At DFW, knowledge of the arrival spot also helps the arrival and departure ground controllers coordinate, without explicit communication, whether a departure must hold at a spot for an arrival to taxi across in front of the departure, or may proceed across the spot because the arrival will turn into a spot before reaching the departure.

If the parking gate assigned to an arrival is not yet available, the ramp tower can enter into SMS the earliest time the parking gate will become available, to indicate how long the ATCT must delay the aircraft on the surface before it may enter the ramp. SMS will relay this information to the ground and local controllers via the map display, either using an entry in the data block or coloring the aircraft icon. The same mechanism can be used to indicate when an arrival or group of arrivals must be delayed because the ramp is not available (i.e., an alley needs to be kept clear to allow a priority departure to exit the ramp first).

**Runway Assignment Advisories**

SMS displays the predicted departure runway assignment of reach departure aircraft, based on the active departure scenario and the flight's departure fix, in the second line of the map display data block. The Local, Ground, or TMC can change the SMS-planned runway, which will be reflected in the data block and all other SMS displays. In addition, if SMS recognizes, based on surface surveillance, that the aircraft is being taxied to a different runway, SMS will change the predicted departure runway for the flight.

Ground controllers make exceptions to the departure scenario when assigning runways both to balance runways and, during less busy periods, to assign aircraft to the runway closest to their parking gate to reduce taxi distance. SMS can advise exceptions to the departure scenario; this capability, like any others, can be turned on or off. SMS's flight-specific runway advisory function searches to determine whether a small number of departure runway assignments that are exceptions to the departure scenario could provide a significant reduction in total departure delay. Since these runway assignments would violate the active departure scenario, the search for beneficial alternate runways assignments is constrained by the requirement that the suggested runway assignment cannot cause airborne conflicts. Airport departure conflicts would represent a safety concern and create high controller workload.

These runway assignment advisories can either be displayed directly to the ground controller, who can use or ignore the advisory, or first displayed to the TMC who can filter or approve the advisory before it is presented to the ground controller. At airports where the runway assignment decision must be made prior to aircraft pushback which is controlled by the ramp tower, the TMC must approve exceptions in advance. SMS can be used to communicate the runway assignments for each flight to the ramp tower.

SMS considers both the longer taxi distance and additional flight time when calculating the benefit of a runway assignment. SMS suggests changing the departure runway for a particular flight to reduce the overall departure delays. However, SMS currently constrains the search to flights that would not incur a longer individual delay.

**For the Air Traffic Control Tower Local Controller:**

**Meeting Departure Time Restrictions**

SMS displays information in the map display data block to help controllers meet EDCTs and APREQ release times. SMS receives EDCT constraints from ETMS; release times for flights under APREQ procedures will need to be entered into SMS. SMS displays the takeoff time restrictions in the data block on the ground and local controllers' map displays.

If SMS predicts that a flight will take off earlier than the earliest allowed time, the field in the data block will alternatively display the departure restriction and the number of minutes the flight needs to be delayed. If the predicted takeoff time is after the latest allowed departure time, the data block on the map will alternately display the number of minutes the flight must be expedited. In addition, SMS can notify the ATCT TMC if a flight is predicted to require special attention in order to meet a departure time constraints.

During de-icing operations, the ramp tower can enter the maximum hold-over time before a flight will need to be de-iced again. SMS displays the latest departure time for each flight with a hold-over limit in the data block on the ground and local controllers' map displays. If SMS predicts the flight needs to be expedited to avoid needing to return to the de-icing pad, SMS provides an expedite advisory, similar to that for EDCT and APREQ departure windows.

**Departure Sequence**

SMS plans and recommends to the ground and local controllers a departure sequence for each runway that maximizes the runway throughput subject to wake vortex and downstream traffic management restrictions (e.g., MIT and EDCTs). An additional objective of departure sequencing is to incorporate air carrier priorities to enhance user flexibility without compromising fairness or throughput. SMS provides sequence advisories to the ground controller to aid in constructing an efficient sequence that incorporates user priority when feasible (e.g., does not reduce airport efficiency or increase controller workload). The exact mechanism for providing sequence advisories to the ground controllers may be site specific.

**Rare Nominal Conditions**

**To be determined**

**Failure Conditions**

**To be determined**

## 7. Summary of Impacts

### 7.1 Operational Impacts

The ability to predict the future surface situation enables SMS to aid users by advising how to manage some aspects of surface operations to best achieve strategic goals. SMS's planning tools attempt to increase airport throughput (i.e., peak capacity rate), increase the efficiency of surface operations (i.e., minimize the cost of unavoidable delays and their environmental impact), and improve user flexibility (i.e., minimize the impact of delays on air carrier business objectives), without increasing user workloads.

SMS continually updates its advisories to react to the current situation and controller actions and is collaborative between the tower and the air carriers.

The three aspects of SMS (traffic management tool, controller tool, and NAS information tool) can be turned off, as appropriate, for a particular site or user. Its operational impact would be appropriately changed, depending up which feature of SMS was turned on.

### 7.2 Organizational Impacts

**To be determined**

### 7.3 Impacts during Development

SMS is at a very early stage of development. As such, it is difficult to determine the impacts on the user, acquirer, and maintenance organizations during development. It is however required that airline operations personnel and FAA air traffic controllers and traffic managers participate in the development process during demonstration and test phases.

## 8. Analysis of the Proposed System

### 8.1 Summary of Advantages

The following is a list of the potential benefit mechanisms from SMS, discussed in the context of the metrics associated with AATT goals of: Capacity, Flexibility, Efficiency, and Environment.

**Capacity:** SMS's planning tools attempt to increase airport throughput (i.e., peak capacity rate),

**Flexibility:** SMS should improve user flexibility (i.e., minimize the impact of delays on air carrier business objectives), without increasing user workloads.

**Efficiency:** SMS should increase the efficiency of surface operations (i.e., minimize the cost of unavoidable delays and their environmental impact).

**Environment:** SMS should reduce the amount of taxi in and out delays, thus producing both fuel savings and reduced environmental impacts (noise and pollution).

### 8.2 Summary of Disadvantages/Limitations

There are no significant disadvantages or limitations to SMS.

### 8.3 Alternatives and Tradeoffs Considered

None.

## 9. Notes

### Abbreviations and Acronyms

| | |
|---|---|
| AAR | Airport Arrival Rate |
| AATT | Advanced Air Traffic Technologies |
| ACARS | Aircraft Communication and Reporting System |
| ADL | Aggregate Demand List |
| ADS-B | Automatic Dependent Surveillance – Broadcast |
| AOC | Airline Operations Center |
| APREQ | Approval Request |
| ARTCC | Air Route Traffic Control Center |
| ARTS | Automated Radar Terminal System |
| ASDE | Airport Surface Detection Equipment |
| ATC | Air Traffic Control |
| ATCSCC | Air Traffic Control System Command Center |
| ATCT | Air Traffic Control Tower |
| ATIDS | Airport Traffic Information Display System |
| ATMSDI | Air Traffic Management System Development and Integration |
| ATSP | Air Traffic Service Provider |
| CD | Clearance Delivery |
| CDM | Collaborative Decision Making |
| CDR | Coded Departure Route |
| CTAS | Center – TRACON Automation System |
| CTO | Contract Task Order |
| DBRITE | Digital Bright Radar Indicator Equipment |
| DFW | Dallas - Fort Worth |
| DST | Decision Support Tool |
| EDCT | Expected Departure Clearance Time |
| EDP | Expedite Departure Path |
| ETMS | Enhanced Traffic Management System |
| FAA | Federal Aviation Administration |
| FAST | Final Approach Spacing Tool |
| FC | Flight Crew |
| FD | Flight Deck |
| FedEx | Federal Express |
| FFC | Future Flight Central |
| FFP2 | Free Flight Phase 2 |
| FPS | Flight Progress Strips |
| FSM | Flight Schedule Monitor |
| HITL | Human in the Loop |
| IAT | International Air Terminal |
| ID | Identification |
| IEEE | Institute of Electrical and Electronic Engineers |
| JFK | John F. Kennedy International Airport |
| MEL | Minimum Equipment List |

| | |
|---|---|
| MEM | Memphis International Airport |
| MIT | Miles in Trail |
| NAS | National Airspace |
| NASA | National Aeronautics and Space Administration |
| OCD | Operational Concept Description |
| OEP | Operational Evolution Plan |
| PHL | Philadelphia International Airport |
| PDC | Pre-Departure Clearance |
| SMS | Surface Management System |
| TFM | Traffic Flow Management |
| TGUI | Timeline Graphical User Interface |
| TMA | Traffic Management Advisor |
| TMC | Traffic Management Coordinator |
| TMU | Traffic Management Unit |
| TRL | Technology Readiness Level |
| TRACON | Terminal Radar Control (Facility) |